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Dated 14 November 2002

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Request for grant of a patent

The Patent Office
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South Wales NP10 8QQ

1. Your reference GB920020033GB1

2. Patent application number *(The Patent Office will fill in this part)* 0218891.0

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

INTERNATIONAL BUSINESS MACHINES CORPORATION
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United States of America

Patents ADP number *(if you know it)* 519637001

If the applicant is a corporate body, give the country/state of its incorporation

State of New York
United States of America

4. Title of the invention METHOD FOR DATA RETENTION IN A DATA CACHE AND DATA STORAGE SYSTEM

5. Name of your agent *(if you have one)* R J Burt

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S021 2JN

Patents ADP number *(if you know it)* 7903925001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country

Priority App No *(if you know it)*

Date of filing *(day/month/year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date or the earlier application

No of earlier application

Date of filing *(day/month/year)*

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Statement of inventorship and of right to grant of a patent

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South Wales NP10 8QQ

1.	Your reference	GB920020033GB1
2.	Patent application number *(if you know it)*	0218891.0 14 AUG 2002
3.	Full name of the or of each applicant	INTERNATIONAL BUSINESS MACHINES CORPORATION
4.	Title of invention	METHOD FOR DATA RETENTION IN A DATA CACHE AND DATA STORAGE SYSTEM
5.	State how the applicant(s) derived the right from the inventor(s) to be granted a patent	By employment and agreement
6.	How many, if any, additional Patents Forms 7/77 are attached to this form?	1
7.		I/We believe that the person(s) named over the page (and on any extra copies of this form) is/are the inventor(s) of the invention which the above patent application relates to. Signature 13 August 2002 Date
8.	Name and daytime telephone number of person to contact in the United Kingdom	R J Burt Tel: 01962 816646

Enter the full names, addresses and postcodes of the inventors in the boxes and underline the surnames

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If there are more than three inventors, please write their names and addresses on the back of another Patents Form 7/77 and attach it to this form

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REMINDER

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METHOD FOR DATA RETENTION IN A DATA CACHE AND DATA STORAGE SYSTEM

This invention relates to data storage systems. In particular, this invention relates to a method and system for data retention in a data cache.

In existing, well-known write caching systems, data is transferred from a host into a cache on a storage controller. The data is retained temporarily in the cache until it is subsequently written ("destaged") to a disk drive or RAID array.

In order to select the region of data to destage next, the controller firmware uses an LRU (Least Recently Used) algorithm. The use of an LRU algorithm increases the probability of the following advantageous events happening to the data in the cache.

1. Data in the cache may be overwritten with updated data before being destaged, so that write operations from the host result in only one destage operation to the disk, thereby reducing disk utilisation.

2. Data in the cache may be combined with logically-adjacent data (coalesced) to form a complete stride for destaging to a RAID 5 array, thereby avoiding the read-modify-write penalty typically encountered when writing to a RAID 5 array.

3. An attempt by the host to read data which it has recently written may be serviced from the cache without the overhead of retrieving the required data from the disk. This improves the read response time.

Data in the cache must be protected against loss during unplanned events (e.g. resets or power outages). This is typically achieved by including battery backed memory or UPS (uninterruptible power supply) to allow the data to be retained during such events.

However, the provision of such backup power is difficult and expensive so a design decision is often taken such that the controller may not have sufficient power available to retain the contents of all of its cache memory. Consequently, the controller has areas of cache memory which cannot be used for write caching (since the data stored therein would be vulnerable to loss).

data may be added to the head of the second list when the data is destaged. If the data was not read when referenced in the first list, the data may be either maintained in its position in the second list or discarded.

The flag may include a timestamp each time the data is read and the timestamp may be used to prioritise the position of the data reference in the second list.

Data may be partly dirty and partly clean and may be referenced in both the first and second lists.

According to a second aspect of the present invention there is provided a data storage system comprising: a storage controller including a cache; a data storage means; and the cache has a first least recently used list for referencing dirty data which is stored in the cache, and a second least recently used list for referencing clean data; wherein dirty data is destaged from the cache when it reaches the tail of the first least recently used list and clean data is purged from the cache when it reaches the tail of the second least recently used list.

Dirty data which is destaged to a data storage means may have a copy of the data retained in the cache as clean data which is deleted from the first list and added to the second list.

A read command which is a cache miss may fetch data from the data storage means and the data may be retained in the cache with a reference in the second list.

A flag may be provided with each data reference in the first list indicating whether or not the data has been read whilst on the first list. If the data was read when referenced in the first list, the data may be added to the head of the second list when the data is destaged. If the data was not read when referenced in the first list, the data may be either maintained in its position in the second list or discarded.

The flag may include a timestamp each time the data is read and the timestamp may be used to prioritise the position of the data reference in the second list.

Data may be partly dirty and partly clean and may be referenced in both the first and second lists.

According to a third aspect of the present invention there is provided a computer program product stored on a computer readable storage may have subsets referred to as pages. In an example implementation, a page is 4k bytes giving 16 pages in a track. Each of the pages in a track may be dirty, clean or absent. In practice, there may also be subsets of pages.

The first list 104 is for dirty data which is data that has been received from the host 101. The first list 104 is referred to as the LRW (Least Recently Written) list. The second list 105 is for clean data which is data which has been destaged to the data storage means 106 and a copy is retained in the cache 103. The second list 105 is referred to as the LRR (Least Recently Read) list.

Referring to Figure 2, a detail of Figure 1 is provided showing the cache 103 with the LRW list 104 and the LRR list 105. A data region in the cache 103 will always be on at least one list 104, 105 and may be on both lists.

When the dirty data is initially stored 200 in the cache 103, a corresponding entry 201 is created for it on the dirty LRW list 104. When the data is destaged and marked clean, it is deleted from the LRW list 104 and added 202 to the LRR list 105.

Additionally, a data region may be partly dirty and partly clean. As described above, a data region in the form of a track may have some dirty pages and some clean pages. In this case the track would be on both lists 104, 105, since it must be possible to find it both when searching for a destage candidate and when searching for a purge candidate. Individual pages can be destaged or purged, rather than doing this at track level.

There is also another route onto the LRR list 105. In a general read/write cache 103, there are read commands from the host 101 which are cache misses. In this case, data is fetched from the data storage means 106 and may be retained in the cache 103 to satisfy further read commands from the host 101. A corresponding entry 203 is made for the data on the LRR list 105.

This is particularly beneficial in an environment where the storage controller 102 may be accessed from multiple hosts, since multiple hosts often utilise some regions of the disks for storing shared data and consequently multiple hosts may read the same disk region frequently.

There is a problem of how to assign suitable priority to data which was dirty but has been destaged so is now marked as clean. This data region needs to be deleted from the LRW list and, potentially, added to the has been read whilst dirty, the data descriptor is sent 308 to the head of the LRR list. If the data has not been read whilst dirty, the data is discarded.

The following is a detailed description of the described method. The following should be noted.

- Virtual Track (VT) is the jargon used for a data region in the cache, which contains some dirty data, some clean data or both.
- Cache directory (CD) is the jargon used for the overall directory of cache elements.
- To be considered for a read or write hit, or for destaging or purging, a VT must be in the CD.

Two queues are maintained:

LRW queue of VTs with ANY pages containing some dirty data.
LRR queue of VTs with ANY pages containing no dirty data.

General Rules:

- VTs get added/moved to the head of the LRW queue whenever they are populated with one or more dirty sectors.

- VTs get added/moved to the head of the LRR queue whenever they are read and contain a clean page.

- VTs which get read have their "read" flag set.

- When a VT which is not already on the LRR queue is destaged and marked clean, it is added to the head of the LRR queue if the "read" flag is set. Otherwise it is deleted.

Rules in detail:

Dirty VT inserted into CD:
The VT is added to the head of the LRW queue.

Clean VT inserted into CD:
The VT is added to the head of the LRR queue.

Dirty data merged into VT in LRW queue:
The VT is moved to the head of the LRW queue.

Dirty data merged into VT in LRR queue:

The described method particularly improves write performance for RAID 5 storage arrays by permitting data coalescing into full-stride writes.

The described technology could be used in disk drives, disk controllers/adapters and file servers.

Modifications and improvements may be made to the foregoing without departing from the scope of the present invention.

8. A method as claimed in any one of the preceding claims, wherein data is partly dirty and partly clean and is referenced in both the first and second lists (104, 105).

9. A data storage system comprising:

a storage controller (102) including a cache (103);

a data storage means (106); and

the cache (103) has a first least recently used list (104) for referencing dirty data which is stored in the cache (103), and a second least recently used list (105) for referencing clean data;

wherein dirty data is destaged from the cache (103) when it reaches the tail of the first least recently used list (104) and clean data is purged from the cache (103) when it reaches the tail of the second least recently used list (105).

10. A data storage system as claimed in claim 9, wherein dirty data which is destaged to a data storage means (106) and a copy of the data is retained in the cache (103) as clean data is deleted from the first list (104) and added to the second list (105).

11. A data storage system as claimed in claim 9 or claim 10, wherein a read command which is a cache miss fetches data from the data storage means (106) and the data is retained in the cache (103) with a reference in the second list (105).

12. A data storage system as claimed in any one of claims 9 to 11, wherein a flag is provided with each data reference in the first list (104) indicating whether or not the data has been read whilst on the first list (104).

13. A data storage system as claimed in any one of claims 9 to 12, wherein, if the data was read when referenced in the first list (104), the data is added to the head of the second list (105) when the data is destaged.

14. A data storage system as claimed in any one of claims 9 to 13, wherein, if the data was not read when referenced in the first list (104), the data is either maintained in its position in the second list (105) or discarded.

ABSTRACT

METHOD FOR DATA RETENTION IN A DATA CACHE AND DATA STORAGE SYSTEM

A method for data retention in a data cache and a data storage system are provided. The data storage system (100) includes a storage controller (102) with a cache (103) and a data storage means (106). The cache (103) has a first least recently used list (104) for referencing dirty data which is stored in the cache (103), and a second least recently used list (105) for clean data in the cache (103). Dirty data is destaged from the cache (103) when it reaches the tail of the first least recently used list (104) and clean data is purged from the cache (103) when it reaches the tail of the second least recently used list (105).

FIG. 1

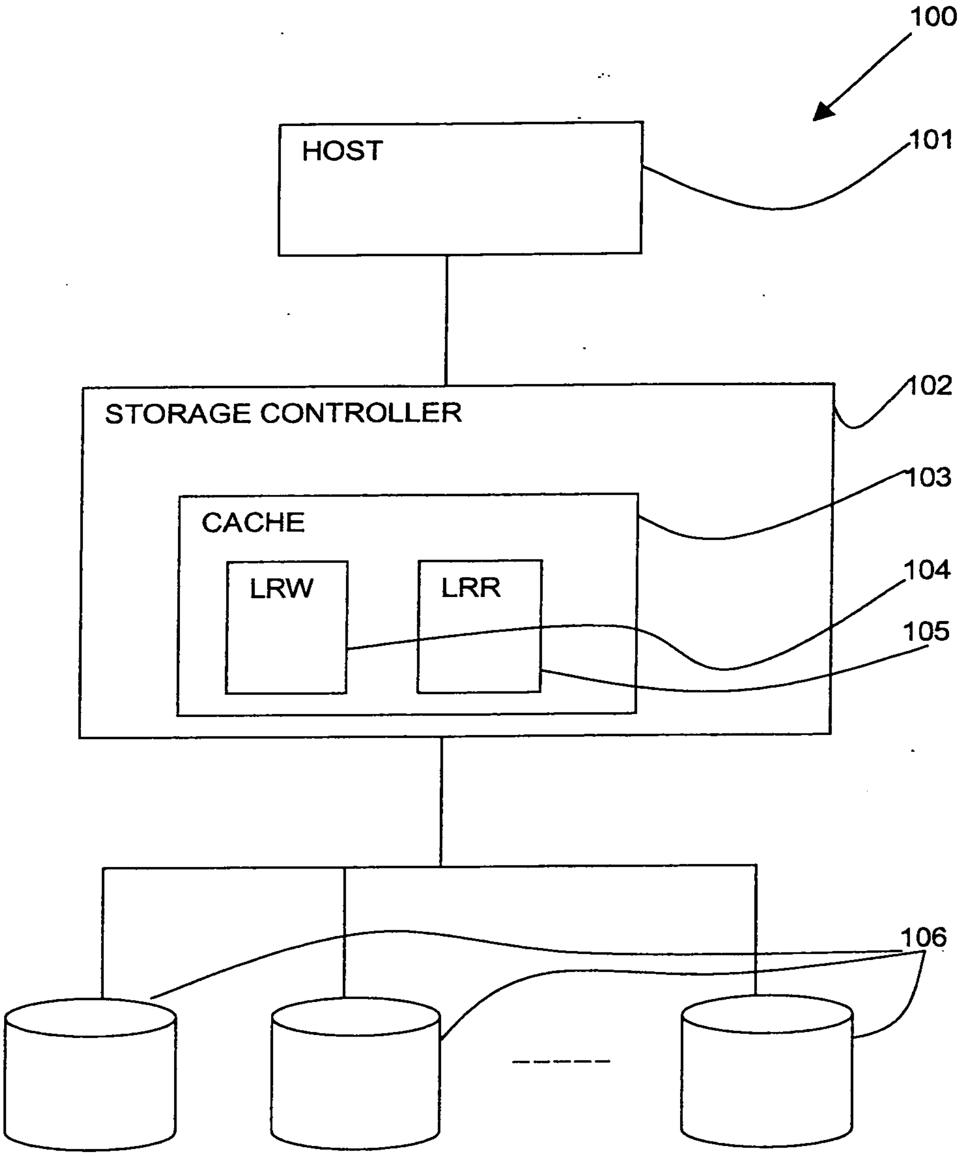

100
HOST
101
STORAGE CONTROLLER
102
CACHE
103
LRW
LRR
104
105
106

FIG. 2

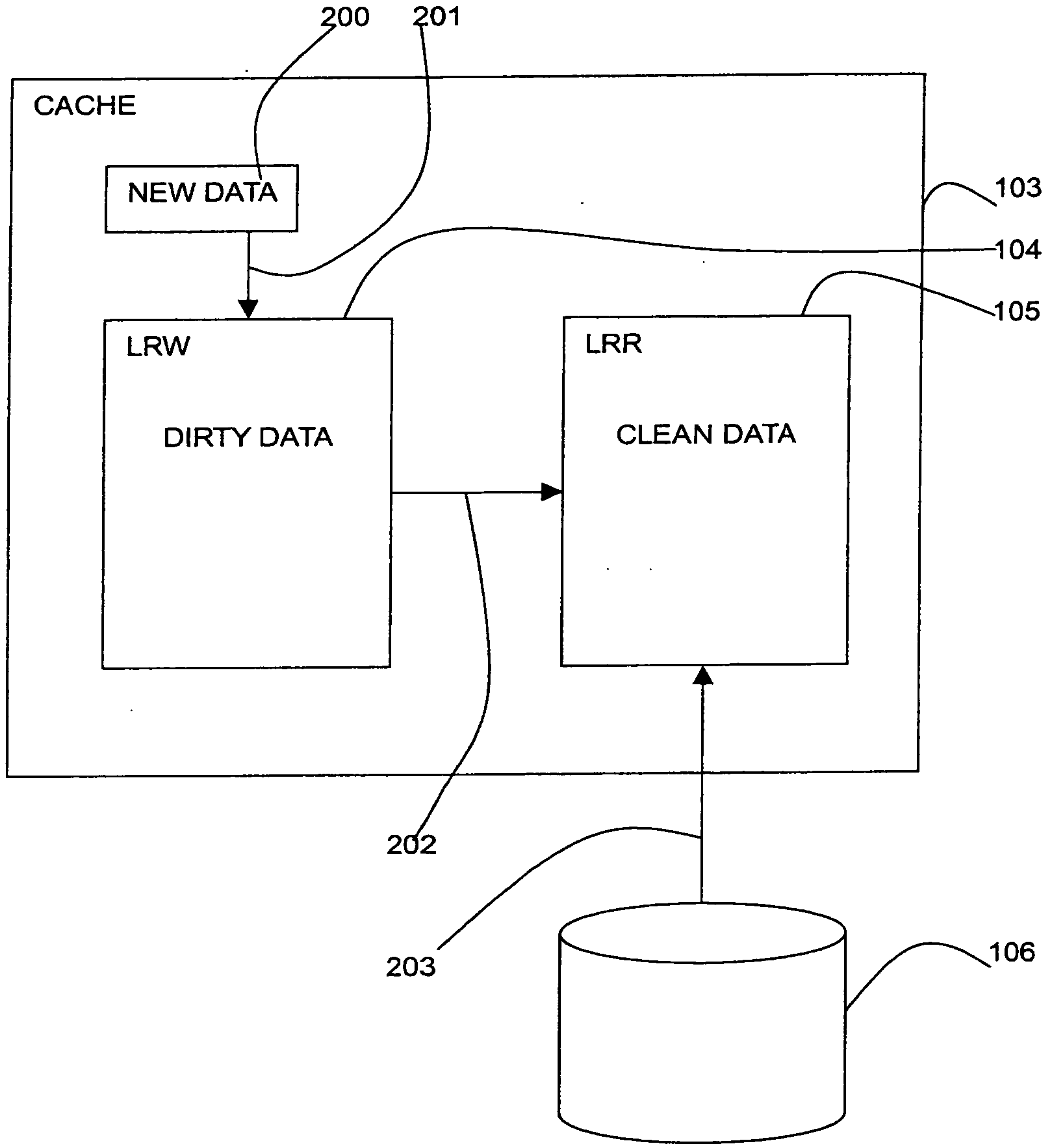
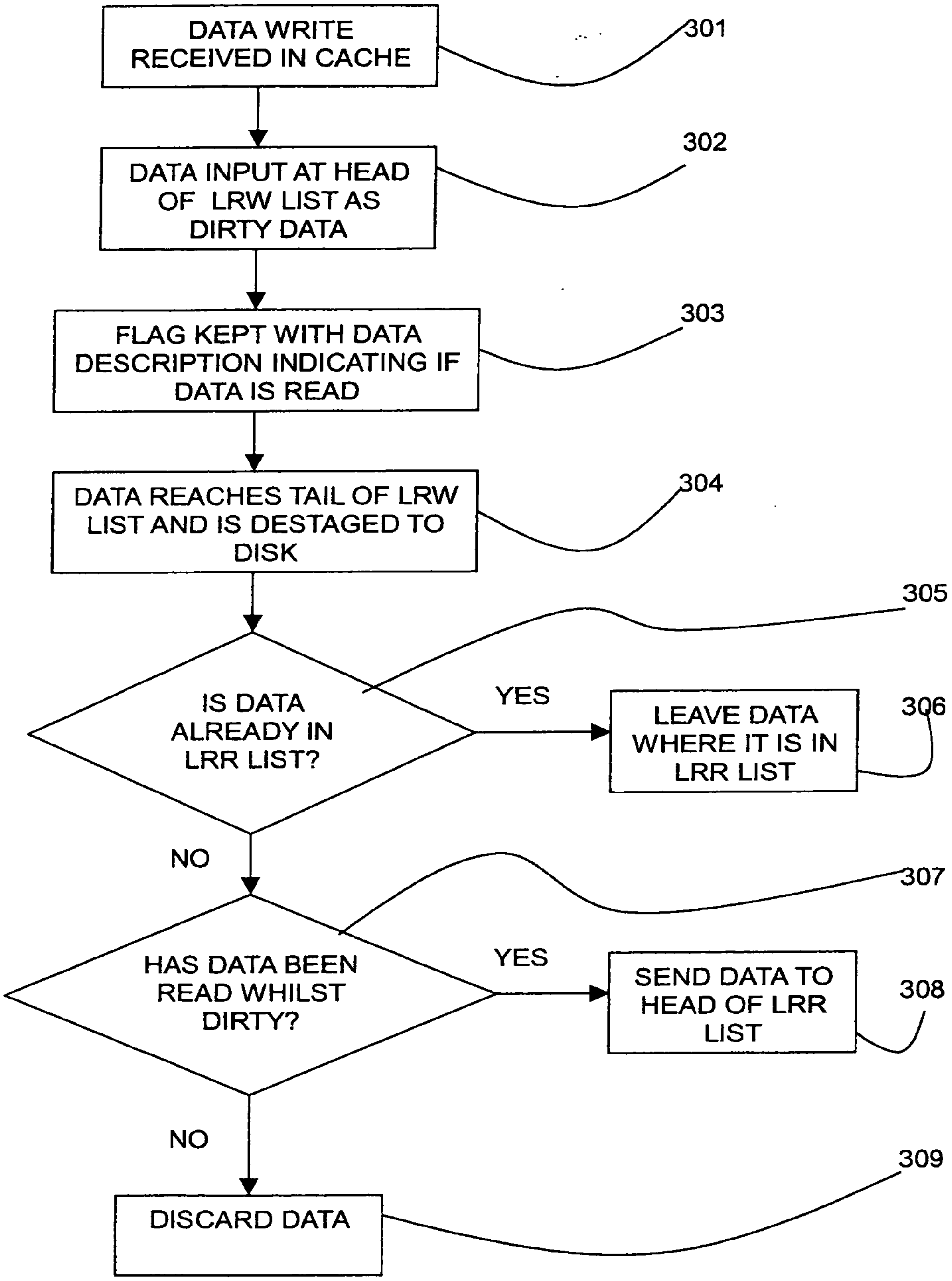

200
201
CACHE
NEW DATA
103
104
105
LRW
DIRTY DATA
LRR
CLEAN DATA
202
203
106

FIG. 3


DATA WRITE RECEIVED IN CACHE
301
DATA INPUT AT HEAD OF LRW LIST AS DIRTY DATA
302
FLAG KEPT WITH DATA DESCRIPTION INDICATING IF DATA IS READ
303
DATA REACHES TAIL OF LRW LIST AND IS DESTAGED TO DISK
304
305
IS DATA ALREADY IN LRR LIST?
YES
LEAVE DATA WHERE IT IS IN LRR LIST
306
NO
307
HAS DATA BEEN READ WHILST DIRTY?
YES
SEND DATA TO HEAD OF LRR LIST
308
NO
DISCARD DATA
309